Reduced Gun Barrel Erosion with Advanced Gun Propellants

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39thGun & Ammunition Symposium
San Diego, CA
9-12 April 2001

Gun Barrel Erosion

- Highly complicated process where interactions occur
  - Short time
  - High velocity
  - High pressure
- Mechanical
- Thermal
- Chemical ⇐
  - Topic of this presentation

Gun Barrel Erosion

- Thermal effects ... Direct function of Tv
  - Adiabatic isochoric flame temperature
- Single base ... Generally low erosion
- Double-base ... Generally erosive
- Triple-base ... Generally low erosion
- Nitramine (RDX-HMX) propellants
  - Traditionally thought to be erosive
  - Regardless of Tv
  - Conflicting data

Advanced Gun Propellants

- Higher energy propellants being developed
- Utilize “new” ingredients
- C-H-O-N stoichiometry differ from current
- Combustion products differ
- Erosion of gun barrels may differ
- 1995 Gun & Ammo paper ... Phoenix Mtg
- 1996 Erosion paper by Arpad Juhasz - ARL

Advanced + Future Gun Propellants
Focus on Higher Velocity

- Impetus > 1300 Joules/gram
- Flame temperature < 3500ºK
  - Preferably < 2500º-2700ºK
- Loading density > 1.10 g/cc
  - Preferably > 1.2 g/cc ... Increased energy-density
- Tailored burning rate
  - Increased progressivity
- All of the above require “new” ingredients
  - Not in service now

Typical Gun Propellants

- Single-base
  - Vieille
- Double-base
  - JA-2
- Triple-base
  - M30 - 47% NQ
- Advanced ... Currently under development
- Future ... 10-20 yrs

Advanced Gun Propellants
World-wide Research

- RDX-TPE — US - Germany - France
- RDX-NC-CAB — US - Germany - Sweden
- RDX-GAP — Germany - France - Japan
- RDX-CAN — Japan
- RDX-HTPB — France
- CL-20 - TPE — US - Germany
- CL-20 - NC-CAB — Germany

- Other compounds — US-Germany-Sweden-Japan
  - High nitrogen compounds

New Ingredients
Beyond SB - DB - TB

- Well-known
  - RDX
  - HMX
- Others … High nitrogen
  - CL-20
  - FOX-7 and FOX-12
  - TAGZT and HzTz
  - Furazans
  - Tetrazoles
  - Triaminoguanidine salts

Comparison of Propellants

	DB	Advanced
Impetus – J/g	1157	1175
Flame temp - ºK	3458	2808
Moles gas/kg	40.3	50.3
Oxygen balance	-31	-55

C-H-O-N Stoichiometry

	DB	Advanced
C	1.00	1.00
H	1.46	1.89
O	1.79	1.15
N	0.50	1.41

Combustion Products
Moles gas/kg

	DB	Advanced
CO	15.0	18.4
CO2	5.2	0.5
H2	3.8	14.9
H2O	10.9	2.8
N2	5.1	13.3

Gas Composition
Mole fraction

	DB	Advanced
CO	0.38	0.37
CO2	0.12	0.01
H2	0.10	0.29
H2O	0.27	0.06
N2	0.13	0.27

Future Gun Propellants
Next 10-20 Years

- New high-nitrogen compounds
  - Increased H and N
  - Decreased C and O
- More energy (impetus) ... > 1400 Joules/g
- Higher density charges
- Tailored burning rate
  - Faster burning
  - Slower burning

Future Gun Propellant
Speculation

- Stoichiometry

- C 1.00
- H 2.51
- O 1.00
- N 2.48

- Combustion products
  - mole fraction
- CO 0.27
- CO2 0.00
- H2 0.33
- H2O 0.02
- N2 0.35

- H2 + N2 ... dominant
- CO2 + H2O ... nil

Erosion Testing

- Typically done in closed bomb
- Blow-out rupture disk + orifice (nozzle)
- Nozzle weighed before and after firing
- Weight loss correlated with propellant properties
- Traditionally, high Tv $\Rightarrow$ high erosion
- Gas composition involved also
  - Japan
  - Germany
  - Switzerland
  - US - ARL - Benet

Erosion Testing

- Japan ... Kimura's research
  - High energy LOVA propellants for tank cannon
- Major parameters affecting erosion
  - Increased H2 ... probably good
  - Increased N2 ... best
  - Reduced CO ... definitely better
  - Reduced CO2 ... definitely better
  - Reduced H2O ... definitely better
- Overall ... Expect improvements
  - Less erosion

Advanced Gun Propellants
Summary

- Will contain “new” energetic compounds
- C-H-O-N stoichiometry will be different
  - Increased H and N
  - Reduced C and O
- Combustion products will be different
  - Increased H_2 + N_2
  - Reduced CO_2 + H_2O
- Gun barrel erosion may be different
- Evidence says erosion may be better
  - At comparable Tv

Acknowledgements

- Joe Flanagan - Consultant
- Arpad Juhasz - Retired ARL
- Charlie Leveritt - ARL
- Al Stern - NSWC/IH
- Tom Brill - University of Delaware
- Woody Waesche - SAIC
- Helena Bergmann - FOA/Sweden
- Dietmar Mueller - ICT/Germany
- Rudi Heiser - Weil-am-Rhein/Germany
- Serge De Boni - NitroChemie/Switzerland
- Beat Vogelsanger - NitroChemie/Switzerland